THE LEFT AURICULAR ELECTROKYMOGRAM IN MITRAL STENOSIS

BY

P. H. DAVISON† and R. G. EPPS

From the Department of Cardiology, Brompton Hospital

Received February 12, 1953

The surgical treatment of mitral stenosis has created the need for accurate assessment of the morbid anatomy of the diseased valve before operation. Clinical examination of the heart has proved the most reliable means to this end (Baker *et al.*, 1952) but it is common experience that significant degrees of mitral regurgitation occasionally defy clinical detection, and for this reason other methods of assessment are being employed. These include fluoroscopic observation of left auricular movement.

The electrokymograph developed by Henny *et al.* (1947) provides a means of recording the border movements of the cardiac silhouette, allowing their form and timing to be related to the major events of the cardiac cycle. This technique has been extensively used in studying the movement of both normal and diseased hearts (Luisada *et al.*, 1948, 1949; Akman *et al.*, 1950; Davies and Venning, 1952).

This paper reports a study of left auricular movement by electrokymography in a group of patients with severe mitral valvular disease who were referred for surgical relief and a small series of control subjects.

Methods

A standard Sanborn electrokymograph was employed and the output fed into the D.C. amplifier of one channel of a Sanborn poly-viso direct-writing oscillograph. A simultaneous phonocardiogram or electrocardiogram recorded on a second channel of the oscillograph gave the time relationship of the electrokymographic tracing to the cardiac cycle. A screening current of 3·5 to 4·5 mA was used at 70 kVp.

The left auricular electrokymogram was recorded with the patient upright and rotated into the right anterior oblique position. The posterior border of the left auricle was first defined by barium swallow and any movement observed then recorded by suitable placing of the photo-tube slit. The polarity of the instrument was such that increase in the amount of light falling upon the slit caused a downward movement of the tracing. The slit was placed across the posterior border of the auricle at right angles to it so that backward movement of the border produced an upward or positive deflection of the record and forward movement a downward or negative deflection.

When the normal cardiac silhouette is observed with the subject rotated into the right oblique position the auricular border is often poorly defined because there is lack of contrast between it and the retro-cardiac space; consequently records of its movement are liable to distortion by variations in density of neighbouring pulmonary vessels (Phillips, 1949). In patients with mitral stenosis there is a relative increase in density of the enlarged auricle with clearer definition of its posterior border, and errors due to exocardiac movements are diminished.

Clinical Material

Studies were made on 39 patients. Twenty-nine of these were suffering from chronic rheumatic heart disease with a sole or predominant lesion of the mitral valve; the remaining 10 had no clinical evidence of valvular disease.

† Travelling Research Fellow of the United Birmingham Hospitals.

The 29 patients with mitral disease were subdivided into three classes according to clinical assessment of the valvular lesion; pure mitral stenosis was thought to be present in 21, predominant mitral stenosis with some incompetence in 6, and pure mitral incompetence in 2. Mitral valvotomy was undertaken in 23—in 17 with pure stenosis and in 6 with a combined mitral lesion—and the pre-operative clinical diagnosis was confirmed in every case by digital palpation of the valve.

The 10 subjects without clinical evidence of valvular disease were six normal healthy controls and four patients with auricular fibrillation only.

Results

It was found possible to classify the electrokymographic records of left auricular border movement into four main types: undulatory, ventricular systolic expansion, ventricular systolic retraction, and absence of movement. Table I shows the incidence of these four electrokymographic patterns in relation to the clinical diagnosis.

TABLE I

Electrokymographic Findings in each Clinical Group

The number of cases with operative confirmation of the clinical diagnosis are given in parenthesis

Diagnosis	No. of. cases	Type of left auricular movement			
		Undulatory	Systolic expansion	Systolic retraction	Absent
Pure mitral stenosis ..	21 (17)	3 (3)	15 (13)	1	2 (1)
Mitral stenosis with incompetence ..	6 (6)	1 (1)	4 (4)	1 (1)	—
Pure mitral incompetence	2	—	2	—	—
Healthy controls	6	4	1	—	1
Auricular fibrillation ..	4	2	—	1	1
Totals	39	10	22	3	4

Undulatory Movement of the Auricle. Here the auricular border is in a state of sinuous movement throughout the cardiac cycle. The number, relative amplitude, and timing of the major positive and negative waves varied greatly from case to case, and only one record (Fig. 1a) resembled the ideal left auricular electrokymogram described by Luisada and Fleischner (1948). A positive wave of short duration at the commencement of ventricular systole representing a transient backward movement of the auricular border was frequently recorded (Fig. 2) but its amplitude and duration in relation to the rest of the tracing did not justify the term ventricular systolic expansion of the auricle.

Undulatory movement was recorded in 10 cases. It was present in four of six normal controls and two of four patients with auricular fibrillation only; four cases of mitral stenosis showed this type of movement and in one of these a significant degree of regurgitation was felt at operation. Typical examples of undulatory auricular movement are shown in Fig. 1 and 2.

Ventricular Systolic Expansion of the Auricle. These records show a single major positive deflection during ventricular systole which represents a sustained backward movement of the auricular border. The form and timing of these electrokymograms reveal that the border moves abruptly backwards at the very onset of ventricular contraction and maintains this position during the ejection phase, returning rapidly to its former position during the earliest phase of ventricular diastole (Fig. 3). This " plateau " form was observed in approximately two-thirds of the cases showing ventricular systolic expansion of the auricle. In the remainder this basic pattern was modified by a late systolic peak and slurring of the down stroke, indicating a continuation of backward movement during the ejection phase and slower return to the resting position (Fig. 5a and 5b), but in

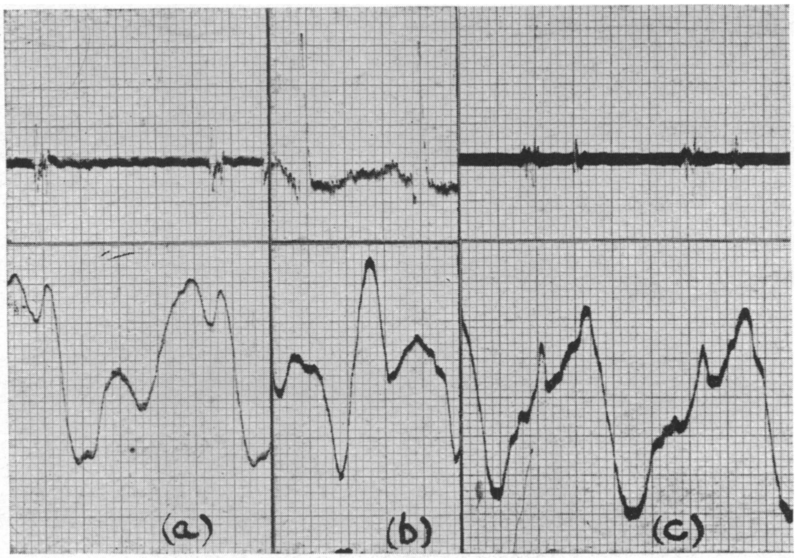

FIG. 1.—Left auricular electrokymograms showing undulatory movement. Simultaneous phonocardiograms in (a) and (c), simultaneous electrocardiogram in (b). (a) and (b) Normal controls. (c) Auricular fibrillation only.

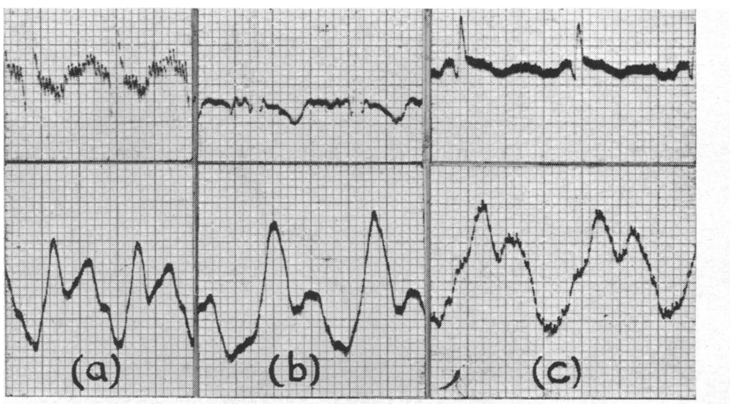

FIG. 2.—Left auricular electrokymograms showing undulatory movement with transient auricular expansion at the commencement of ventricular systole. Simultaneous electrocardiograms. (a) Normal control with tachycardia. (b) Pure mitral stenosis. (c) Mitral stenosis with significant incompetence.

these records also the greater part of the movement takes place during the earliest phases of ventricular systole and diastole. The onset and development of the positive wave was markedly delayed in one patient with gross mitral incompetence (Fig. 5c). During the remainder of diastole there is little or no border movement when the auricle is fibrillating but with sinus rhythm a small presystolic negative wave of auricular systole is frequently observed and a variable degree of movement in mid-diastole (Fig. 3 and 4).

Ventricular systolic expansion of the posterior auricular border was found in 21 of the 29 patients with mitral disease and in one of the 10 control patients. It was observed in approximately three-quarters of the patients with pure mitral stenosis and with equal frequency in the group with predominant mitral stenosis and some incompetence; it was present in both cases of pure mitral

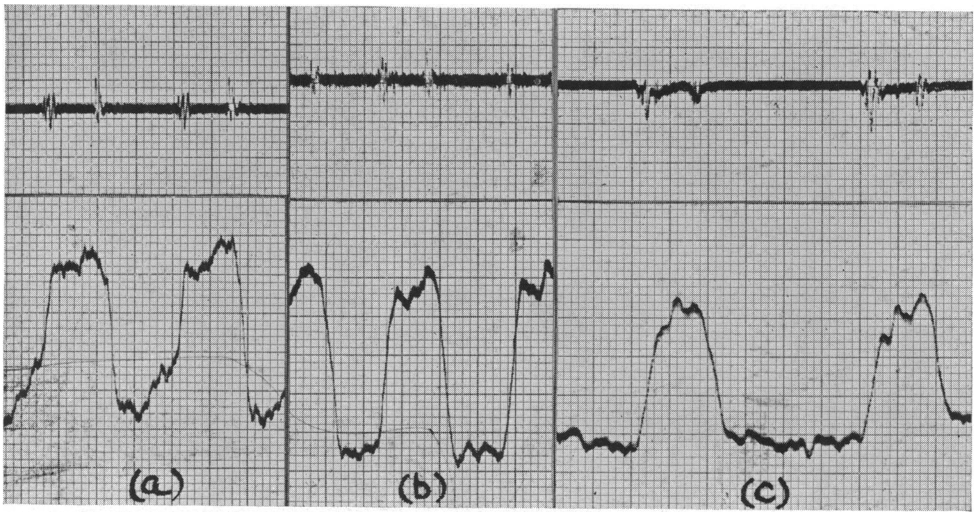

Fig. 3.—Left auricular electrokymograms showing plateau form of ventricular systolic expansion. Simultaneous phonocardiograms. (a) Pure mitral stenosis, sinus rhythm. (b) Pure mitral stenosis, auricular fibrillation. (c) Mitral stenosis with significant incompetence, auricular fibrillation.

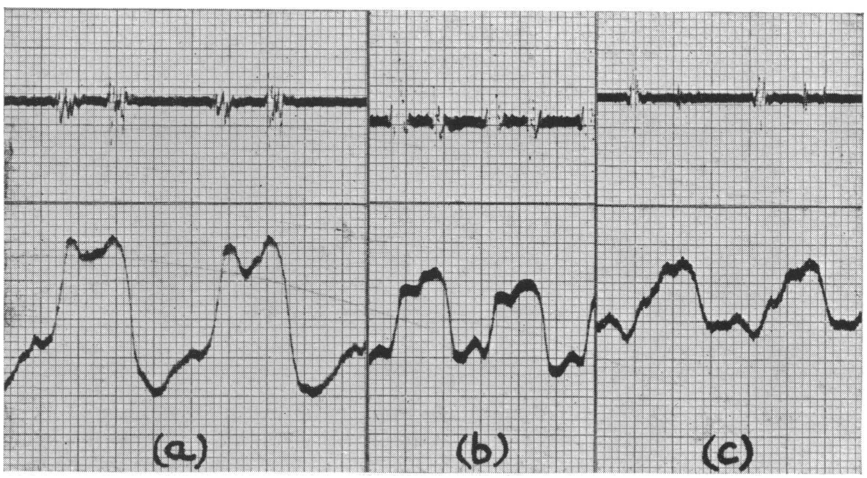

Fig. 4.—Left auricular electrokymograms showing auricular systole followed by ventricular systolic expansion. Simultaneous phonocardiograms. (a) Normal control. (b) and (c) Pure mitral stenosis, sinus rhythm.

incompetence. Of the 17 patients in whom pure mitral stenosis was confirmed by digital palpation of the valve, 13 showed ventricular systolic expansion of the auricular border before operation. A detailed analysis of these findings is given in Table I. The incidence of " plateau " and " peaked " forms of systolic expansion is shown in Table II. A late systolic peak was recorded in three patients with a subsequent diagnosis of pure mitral stenosis at operation.

TABLE II

CASES SHOWING VENTRICULAR SYSTOLIC EXPANSION OF THE POSTERIOR BORDER OF THE LEFT AURICLE

The number of cases with operative confirmation of the clinical diagnosis are given in parenthesis

Diagnosis	Ventricular systolic expansion of left auricle		
	No. of cases	Systolic plateau	Late systolic peak
Pure mitral stenosis	15 (13)	11 (10)	4 (3)
Mitral stenosis with incompetence	4 (4)	3 (3)	1 (1)
Pure mitral incompetence ..	2	—	2
Healthy control	1	1	—
Total	22	15	7

Of the 27 cases of pure or predominant mitral stenosis, 15 had sinus rhythm and 12 had auricular fibrillation; 9 of the 15 in sinus rhythm and 10 of the 12 with auricular fibrillation showed ventricular systolic expansion of the auricular border.

Ventricular Systolic Retraction of the Auricle. Three records of auricular border movement showed a single major negative wave representing retraction of the auricle during ventricular systole (Fig. 6). The pattern resembled a distorted left ventricular electrokymogram and was found in one case of pure mitral stenosis, in one with a combined mitral lesion and predominant stenosis, and in one with auricular fibrillation alone.

Absence of Auricular Movement. In four patients—one normal control, one with auricular fibrillation only, and two with pure mitral stenosis—no movement of the left auricular border could be recorded.

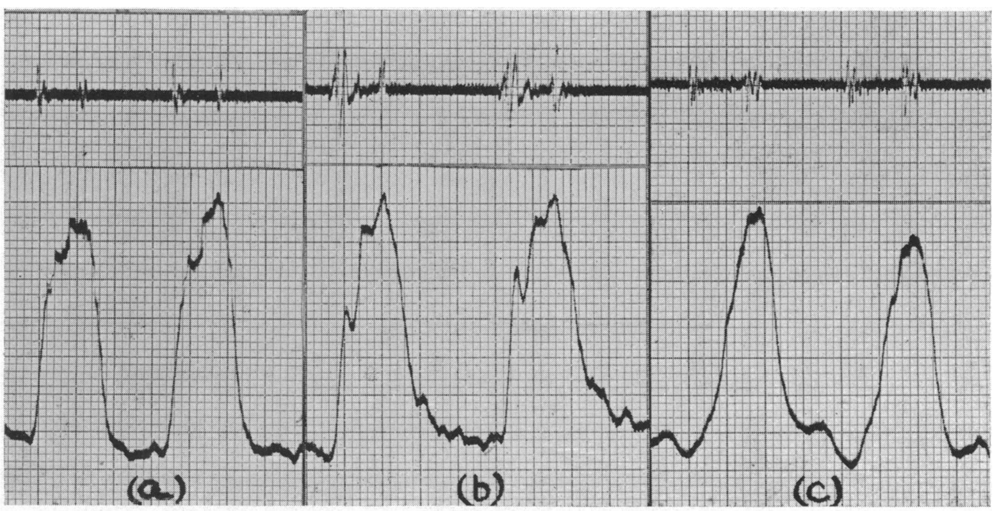

FIG. 5.—Left auricular electrokymograms showing ventricular systolic expansion with late systolic peak. Simultaneous phonocardiograms. (a) Pure mitral stenosis, sinus rhythm. (b) Mitral stenosis with incompetence, auricular fibrillation. (c) Pure mitral incompetence, sinus rhythm.

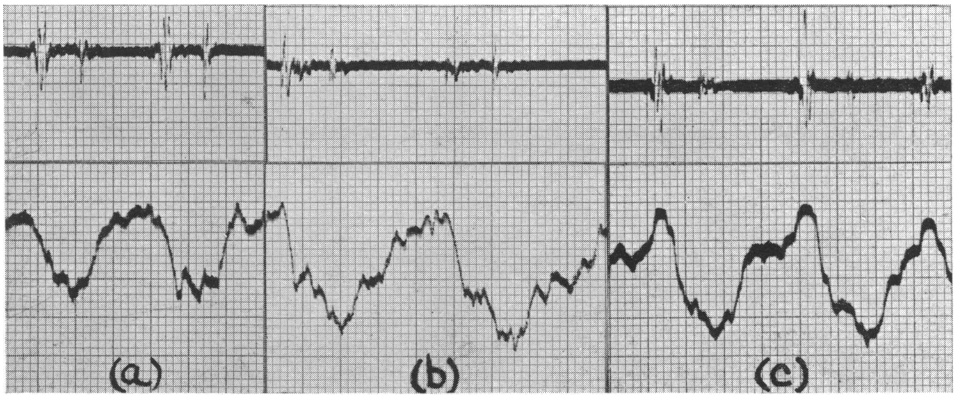

FIG. 6.—Left auricular electrokymograms showing ventricular systolic retraction. Simultaneous phonocardiograms. (a) Pure mitral stenosis. (b) Mitral stenosis with significant incompetence. (c) Auricular fibrillation only.

DISCUSSION

Expansile pulsation of the left auricle during ventricular systole, when observed in the postero-anterior position, is a well recognized and accepted radiological sign of mitral incompetence (Wood, 1950) and the movement is attributed to auricular distension by a regurgitant stream from the left ventricle. The reliability of this sign has been disputed when it is found only on the posterior border of the left auricle (Logan and Turner, 1952).

The findings reported here demonstrate that ventricular systolic expansion of the posterior border of the left auricle is frequently present in pure mitral stenosis and may be absent when mitral stenosis and incompetence are combined. Therefore, this sign is quite valueless as a means of differentiating between pure stenosis and mixed mitral lesions. Nor does the amplitude of movement prove any help, because systolic expansion of the left auricular border, so great that it was clearly visible on the right heart border in the postero-anterior view, has proved compatible with a diagnosis of pure stenosis, confirmed at operation.

Luisada and Fleischner (1948) first described the characteristic electrokymographic pattern of this abnormal movement and attributed it to mitral regurgitation, a conclusion clearly untenable on the present findings. Moreover, Wiggers (1949) has shown that mitral incompetence in animals produces a significant increase in left atrial volume which occurs during the ejection phase of ventricular systole and continues during ventricular relaxation. On these findings, an abrupt backward movement of the left auricular border at the very onset of ventricular contraction and its return during ventricular relaxation are not consistent with regurgitant distension of the auricle. However, direct pressure tracings from the left auricle in mitral stenosis not infrequently bear a close resemblance, in both form and timing, to the " plateau " and " late systolic peak " electrokymograms (Fig. 7), and Lasser *et al.* (1952) have recorded œsophageal pressure pulse patterns in mitral stenosis that have an identical form. These observations suggest that left auricular border movements may reflect pressure changes within the auricle.

Froment *et al.* (1950) attribute abnormal left auricular movement in mitral stenosis to paradoxical retropulsion of the auriculo-ventricular septum into the left auricle during ventricular systole. Elkins *et al.* (1952) consider that the type and degree of left auricular movement in these cases is determined by many factors which include the size of the auricle, flexibility of its wall, presence of mural thrombus and auricular fibrillation, rate of filling from pulmonary veins, transmitted thrust from the right auricle in tricuspid incompetence, and systolic contraction of an hypertrophied right ventricle.

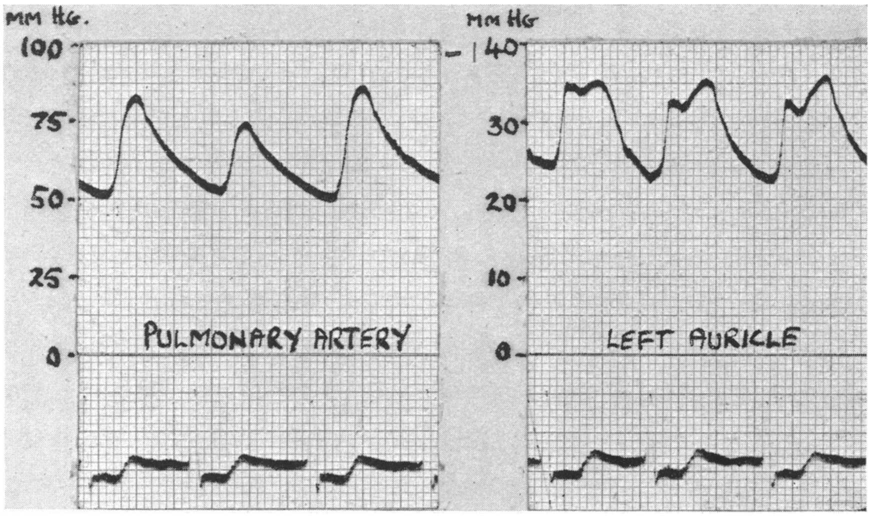

FIG. 7.—Pressure records taken from pulmonary artery and left auricle during operation. Pure mitral stenosis. Simultaneous electrocardiograms. Left auricular pressure pulse curve closely resembles electrokymograms of ventricular systolic expansion of left auricle. Note alternation of pulmonary systolic pressure.

Correlation between certain clinical, electrocardiographic and physiological findings and the type of auricular movement has been looked for in the patients of this series. The incidence of ventricular systolic expansion was significantly higher when mitral stenosis was complicated by auricular fibrillation, a finding in agreement with others (Elkins *et al.*, 1952). Transmitted backward thrust of an hypertrophied right ventricle may contribute to backward movement of the left auricle but there was no correlation between ventricular systolic expansion and such signs of right ventricular hypertrophy as præcordial thrust, the pulmonary arterial pressure, the pulmonary vascular resistance, or the right ventricular predominance in the cardiogram. Nor was the type of auricular movement related to the left auricular pressure as measured by the pulmonary capillary venous pressure, or the left auricular pulse pressure recorded directly at operation. Distensibility of the left auricle and its rate of filling from the pulmonary veins, mobility of the antero-medial cusp of the mitral valve, and bodily movement of the whole heart must all influence the form and degree of left auricular movement. Their several and combined contributions defy assessment.

SUMMARY

Movements of the posterior border of the left auricle have been recorded electrokymographically in the right oblique position in 29 patients with severe mitral disease and 10 control subjects.

Backward movement of the left auricle during ventricular systole was present in 21 of the 29 with mitral disease and in one healthy control. This type of auricular movement was found with equal frequency in patients with pure mitral stenosis and those with mitral stenosis and incompetence. Its incidence was greatest when mitral stenosis and auricular fibrillation were both present. It was unrelated to the degree of right ventricular hypertrophy, to the pulmonary capillary venous pressure, or to the height of the left auricular pulse pressure.

The left auricular electrokymogram proved valueless as a means of differentiating between pure mitral stenosis and mitral stenosis with incompetence.

We wish to express our gratitude to Dr. Paul Wood for his encouragement and helpful criticism. We also wish to thank Dr. G. H. Armitage for advice, Mr. R. C. Brock and Mr. W. Cleland for access to operation notes, and Miss P. Scarlett and Miss D. Anderson for valuable technical assistance.

References

Akman, L. C., Miller, A. J., Silber, E. N., Schack, J. A., and Katz, L. N. (1950). *Circulation*, **2**, 890.
Baker, C., Brock, R. C., Campbell, M., and Wood, P. (1952). *Brit. med. J.*, **1**, 1043.
Davies, L. G., and Venning, G. R. (1952). *Brit. Heart J.*, **14**, 33.
Elkins, M., Sosman, M. C., Harken, D. E., and Dexter, L. (1952). *New Eng. J. Med.*, **246**, 958.
Froment, R., Gonin, A., and Gallavardin, L. (1950). *Arch. Mal. Coeur*, **43**, 678.
Henny, G. C., Boone, B. R., and Chamberlain, W. E. (1947). *Amer. J. Roentgenol.*, **57**, 409.
Lasser, R. P., Epstein, B., and Loewe, L. (1952). *Amer. Heart J.*, **44**, 681.
Logan, A., and Turner, R. (1952). *Lancet*, **2**, 593.
Luisada, A. A., and Fleischner, F. G. (1948). *Amer. J. Med.*, **4**, 791.
——, —— (1949). *Amer. J. Med.*, **6**, 756.
——, and Rappaport, M. B. (1948). *Amer. Heart J.*, **35**, 336.
Phillips, E. (1949). *Permanente Foundation Med. Bull.*, **7**, 25.
Wiggers, C. J. (1949). *Physiology in Health and Disease*. London: Henry Kimpton. p. 799.
Wood, P. H. (1950). *Proc. Roy. Soc. Med.*, **43**, 195.